Vegetation Dynamic Monitoring from Space:

The need for (and how to apply) directional correction

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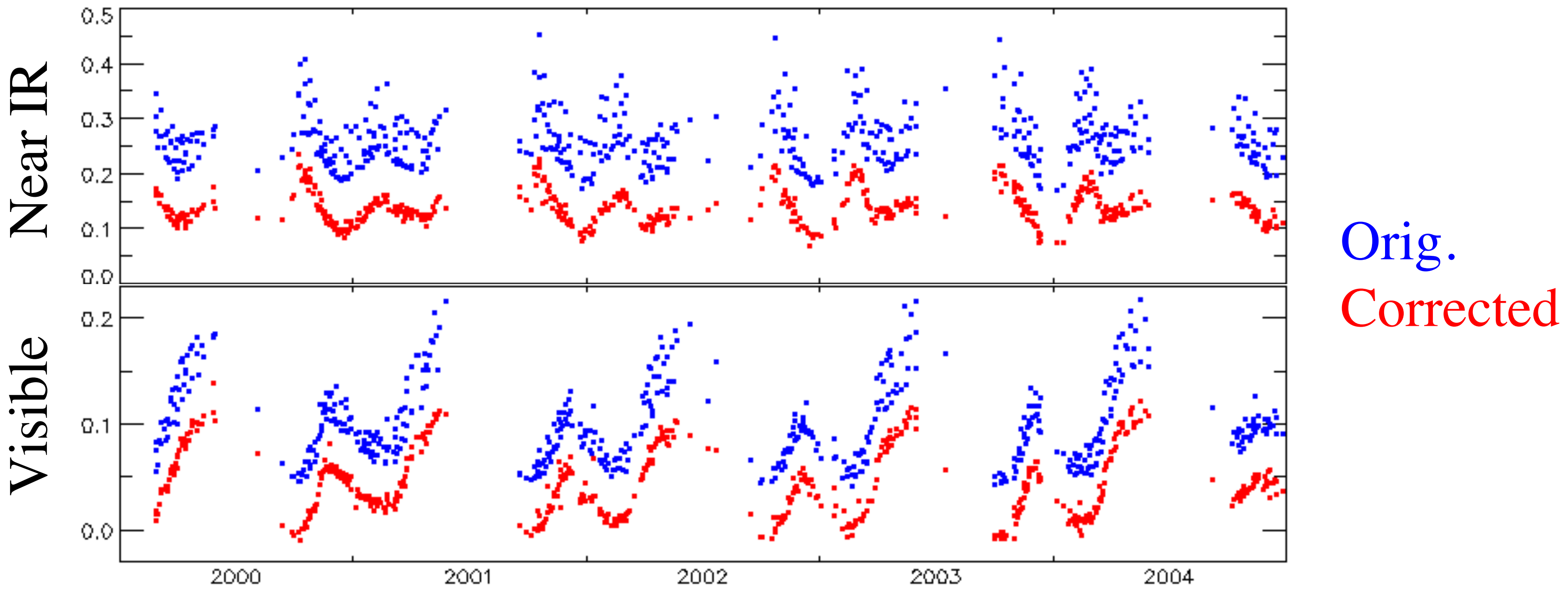
Reflectance time series

Reflectance time series show high-frequency variability

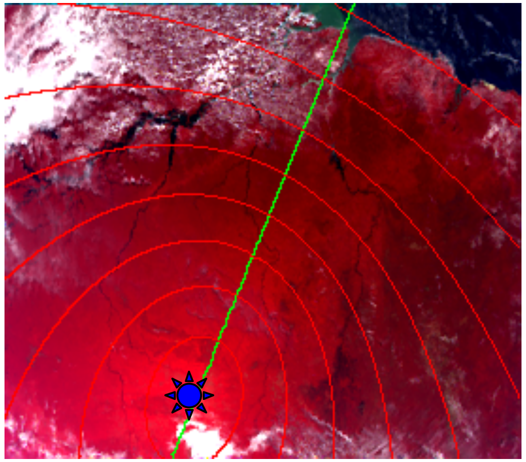
The "noise" is partly due to directional effects.

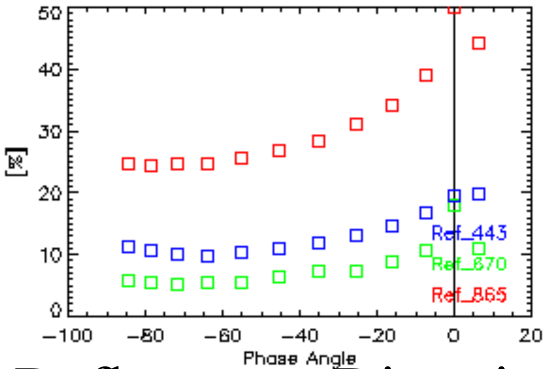
Selection of specific geometries decreases temporal coverage

Can we correct for the directional effect and retain the original temporal resolution ?

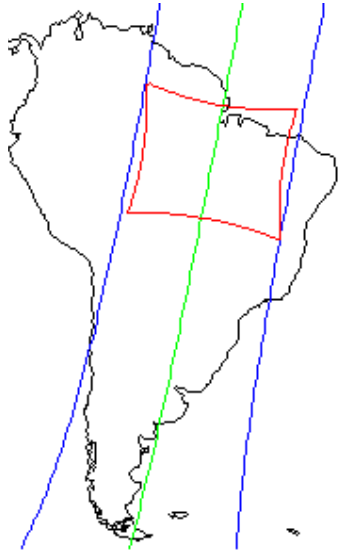


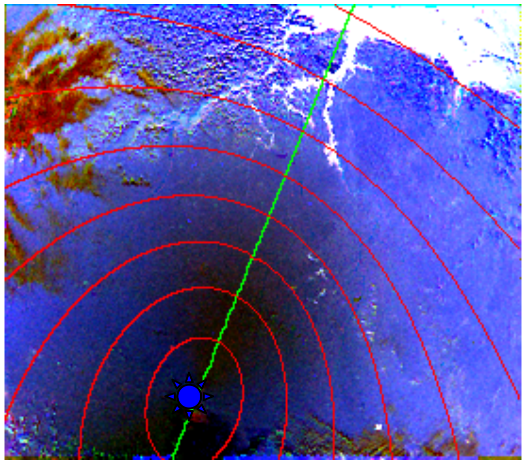
An example of dir. signature

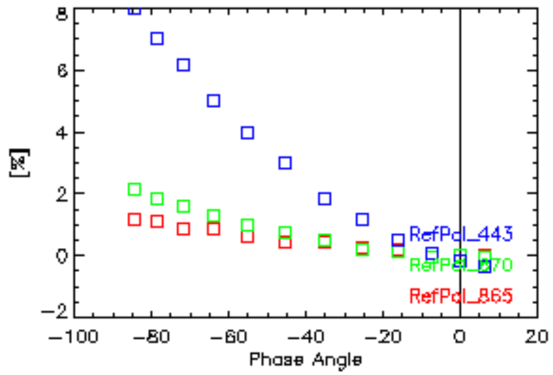




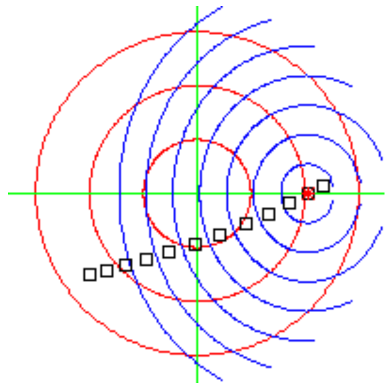
Reflectance Directional Signature



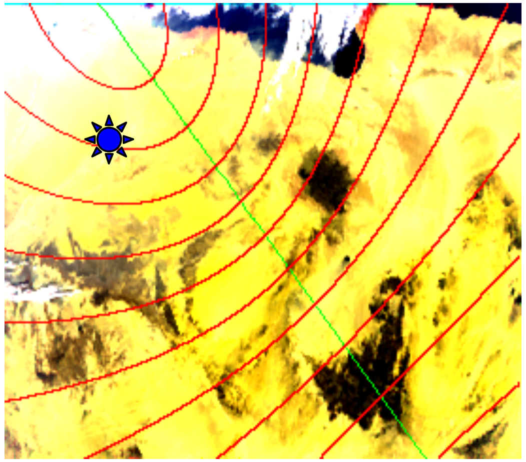


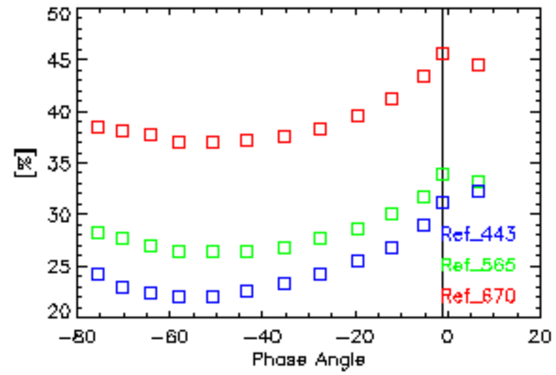


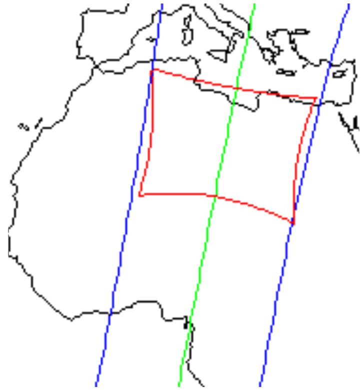
Polarized Reflectance Directional Signature

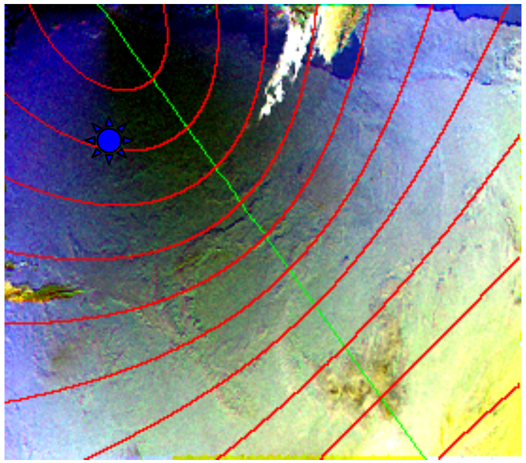


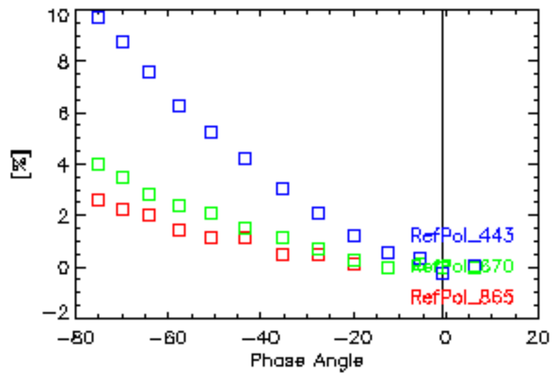
Another one…

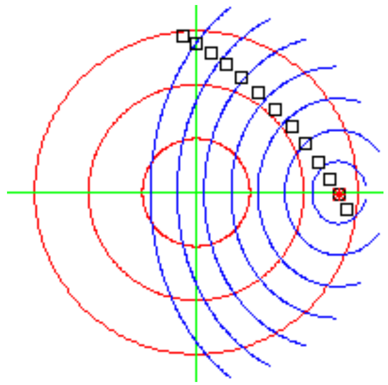



Ref_443
Ref_565
Ref_670
Phase Angle
[%]





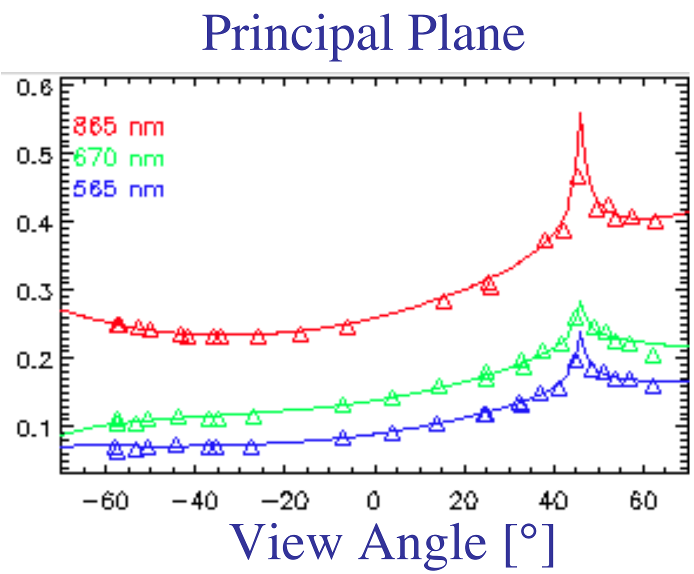

RefPol_443
RefPol_670
RefPol_865
Phase Angle
[%]

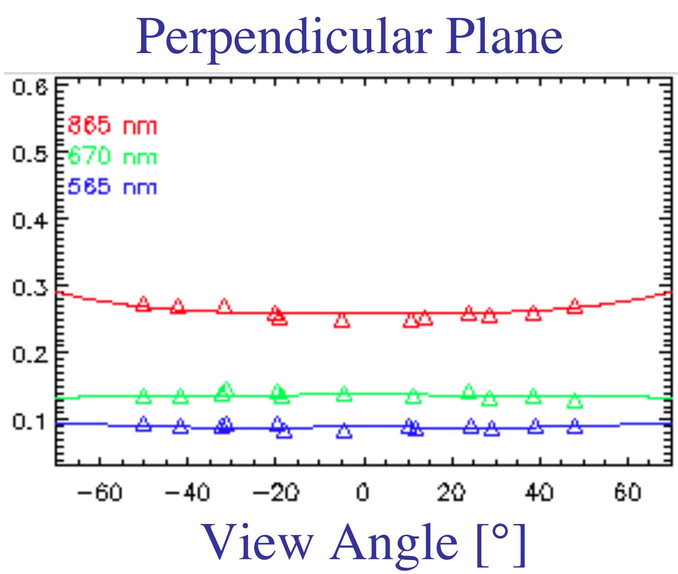


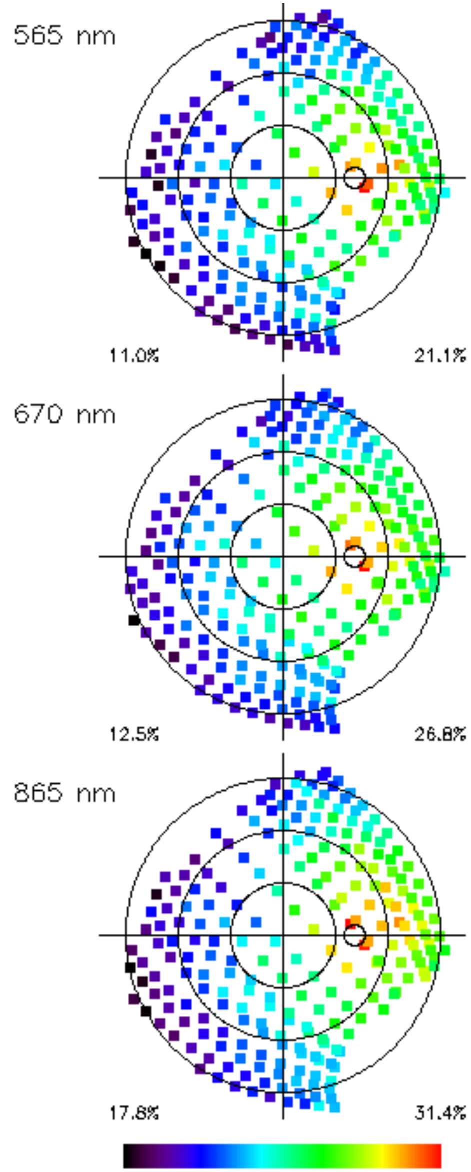
Parasol: “Full” BRDF measurement

Puting together several measurements acquired over several days provide a near complete sampling of the BRDF for view angles < 60°. These are usefull for

- BRDF modeling
- Albedo estimate
- Surface characteristics

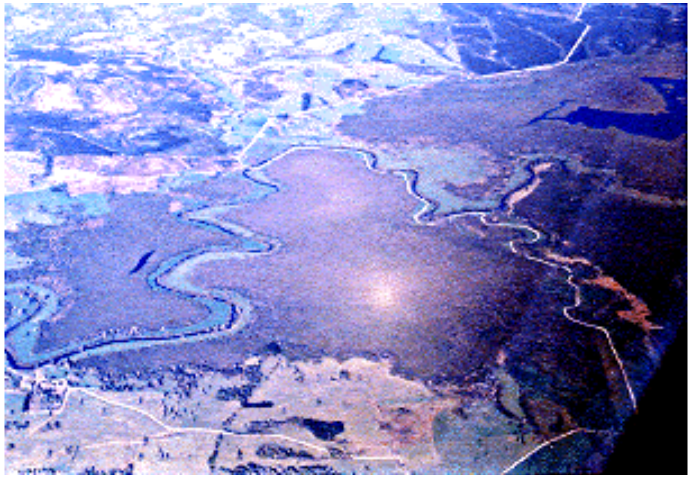






Maignan et al., *Rem. Sens. Env.*, 2004

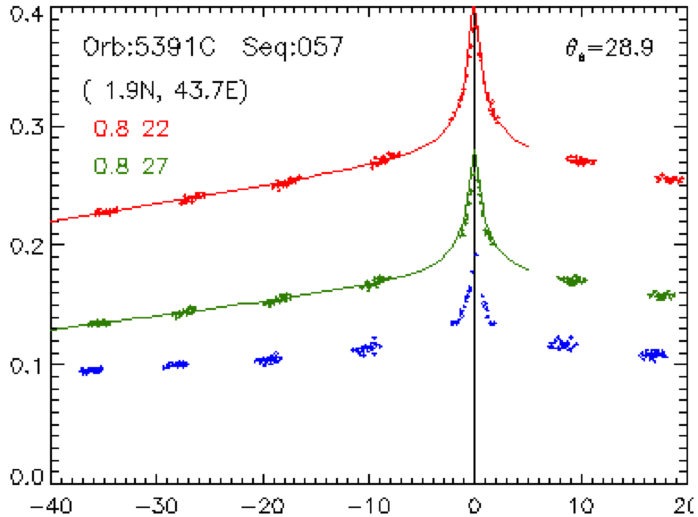
A specific signature : the Hot Spot



The Hot-Spot is a reflectance enhancement a few degrees off backscatter direction

It is well explained by self shadow hiding by vegetation/soil elements

Modeling, confirmed by observation, indicates an enhancement as $1+(1+\xi/\xi_0)^{-1}$



Phase Angle: ξ

Bréon et al., *J. Geophys. Res.*, 2002

Analytical models

Linear models :

$$\rho\,(\theta_s,\ \theta_v,\ \phi) = k_0 + k_1\, F_1(\theta_s,\ \theta_v,\ \phi) + k_2\, F_2(\theta_s,\ \theta_v,\ \phi)$$

Several choices for F_1 and F_2

F_1: Model surface effects (soil roughness)

F_2: Model volume effects (R.T. within canopy)

Analysis of the hot spot have lead to a modification of F_2

$$F_2^{New} = F_2^{Old}\left(1 + \frac{1}{1 + \xi/\xi_0}\right)$$

Non linear models :

RPV [Rahman, Pinty, Verstraete]:

$$\rho\left(\theta_s,\theta_s,\phi\right) = \rho_0\left[\left(\cos\theta_s + \cos\theta_v\right)\left(\cos\theta_s\cos\theta_v\right)\right]^{k-1} P(\xi)\left(1 + R(\xi)\right)$$

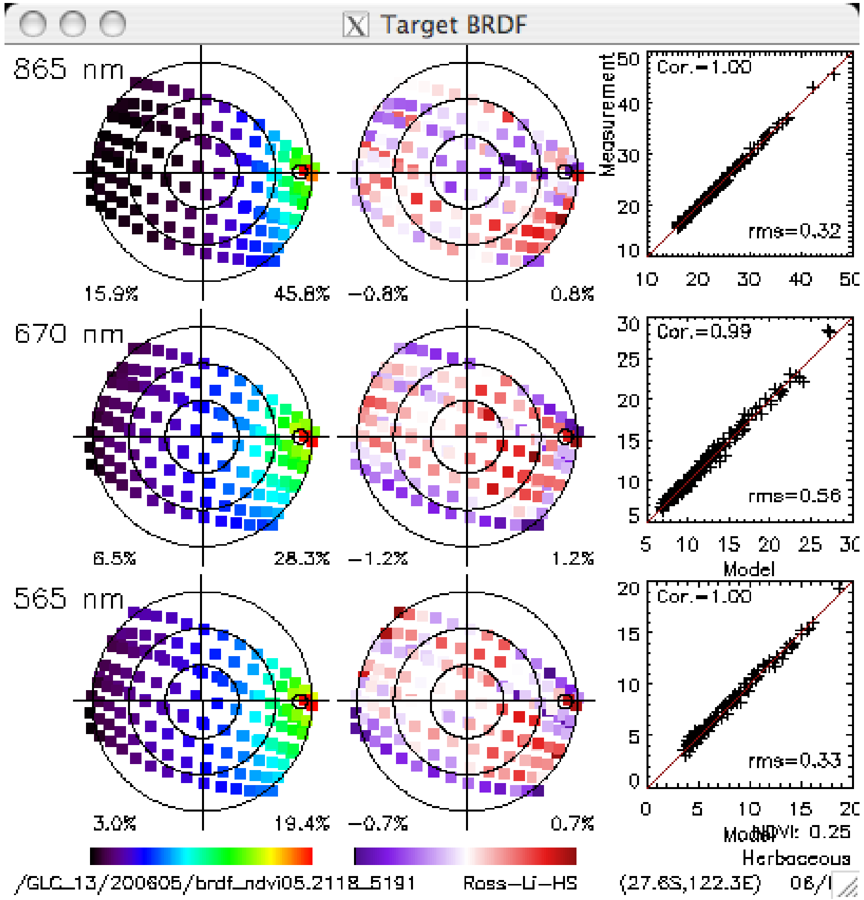
Engelsen : log-linearized version of RPV

Maignan et al., *Rem. Sens. Env.*, 2004

A BRDF database

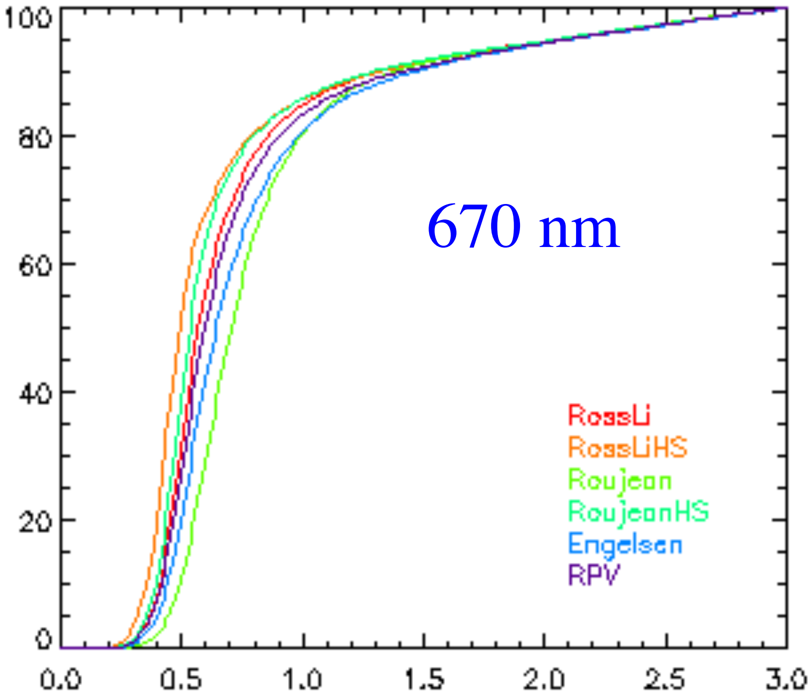
We have developped a database of reflectance measured by Parasol over a wide range of viewing geometries

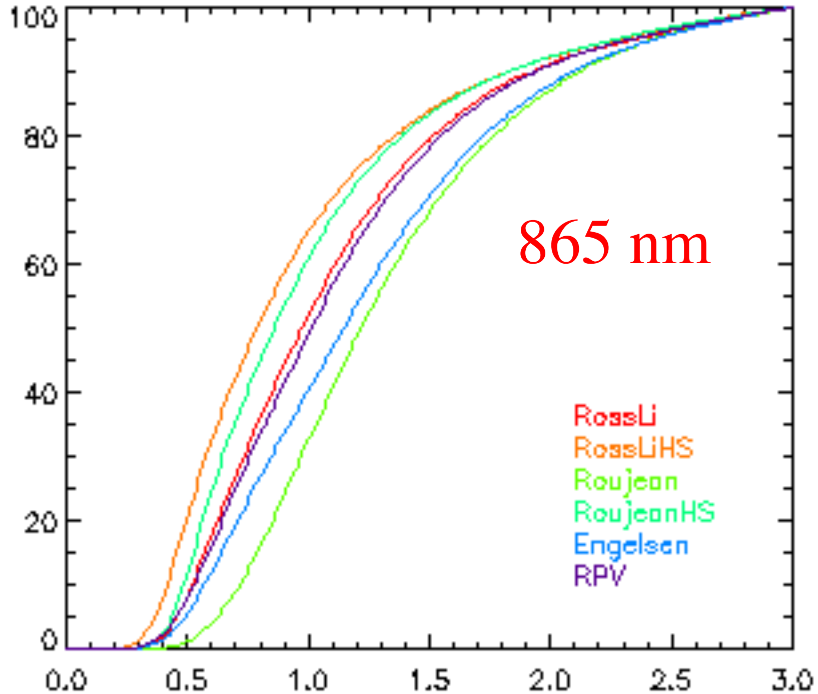
- Corrected for atmospheric effects (transm. and scat.)
- Sorted by surface type
- Selected "best" targets
  - Homogeneity
  - Many obs. over the year
  - "Clean" measurements
- Simple format, limited volume
- Display and analysis tool



Available from http://postel.mediasfrance.org

Which is the "best" model ?



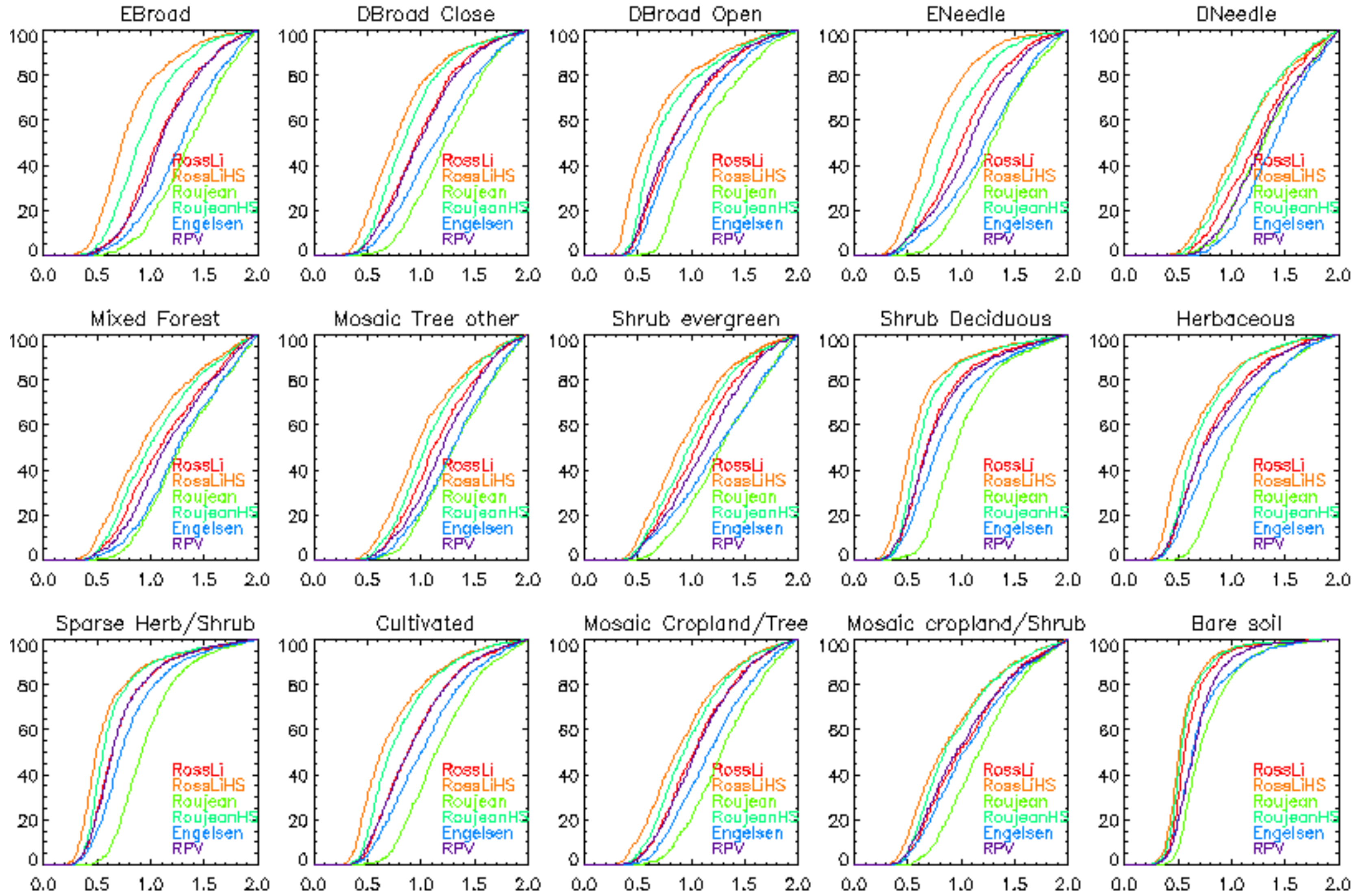


Cumulative histogram of reflectance [%] error of fit.

- Look for the parameters for a best fit (invert the model)
- Compute error of fit
- Among the 6 tested models, *RossLiHS* allows the best fit
- Clear improvement when using *Hot Spot* correction

Maignan et al., *Rem. Sens. Env.*, 2004

Per biome… [865 nm]



The RossLiHS analytical model is the best for all surface types

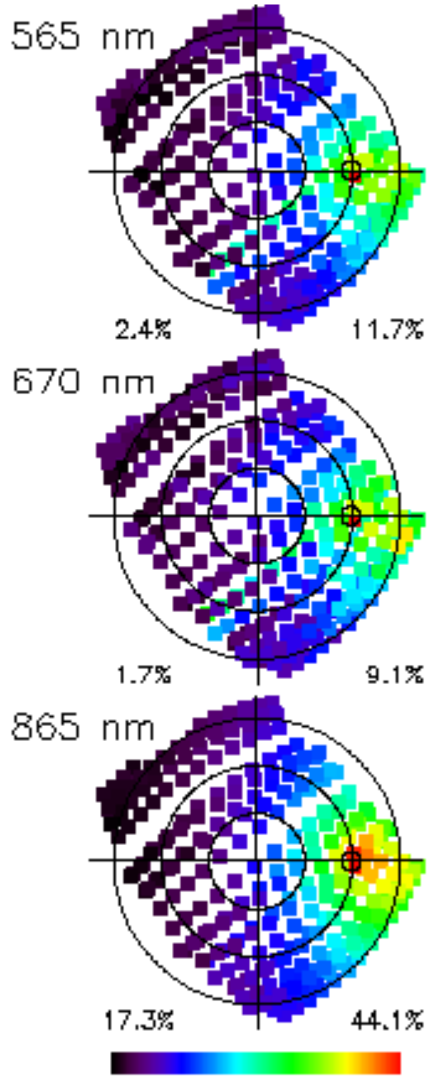
Modeling per biome

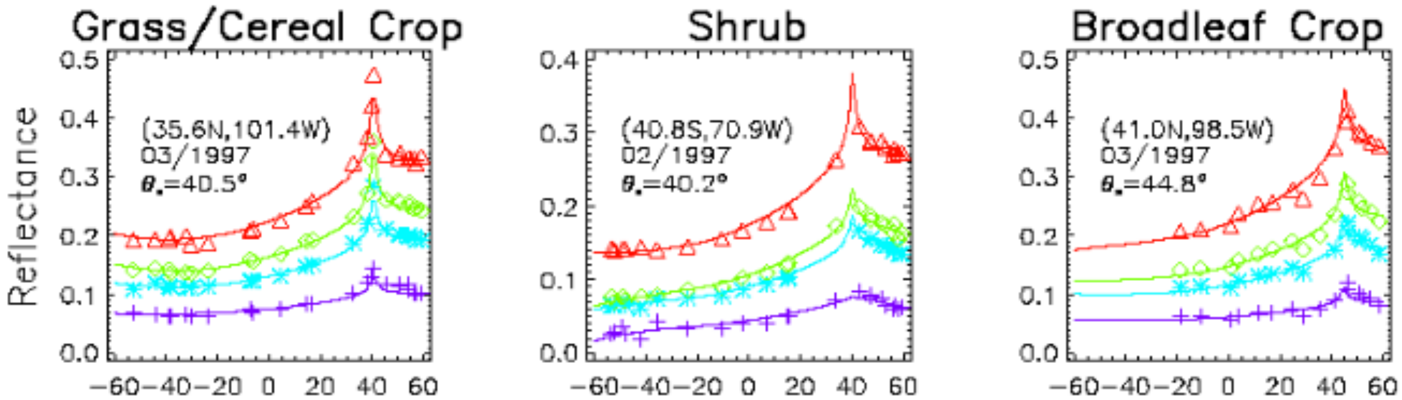
The Bidirectional Signature is

$$BS(\theta_s,\theta_v,\varphi) = 1 + \frac{k_1}{k_0} F_1(\theta_s,\theta_v,\varphi) + \frac{k_2}{k_0} F_2(\theta_s,\theta_v,\varphi)$$

Within a given biome, the variability of the directional signature is rather small

We defined "typical" directional signature (i.e. k_1/k_0 and k_2/k_0) for each biome.





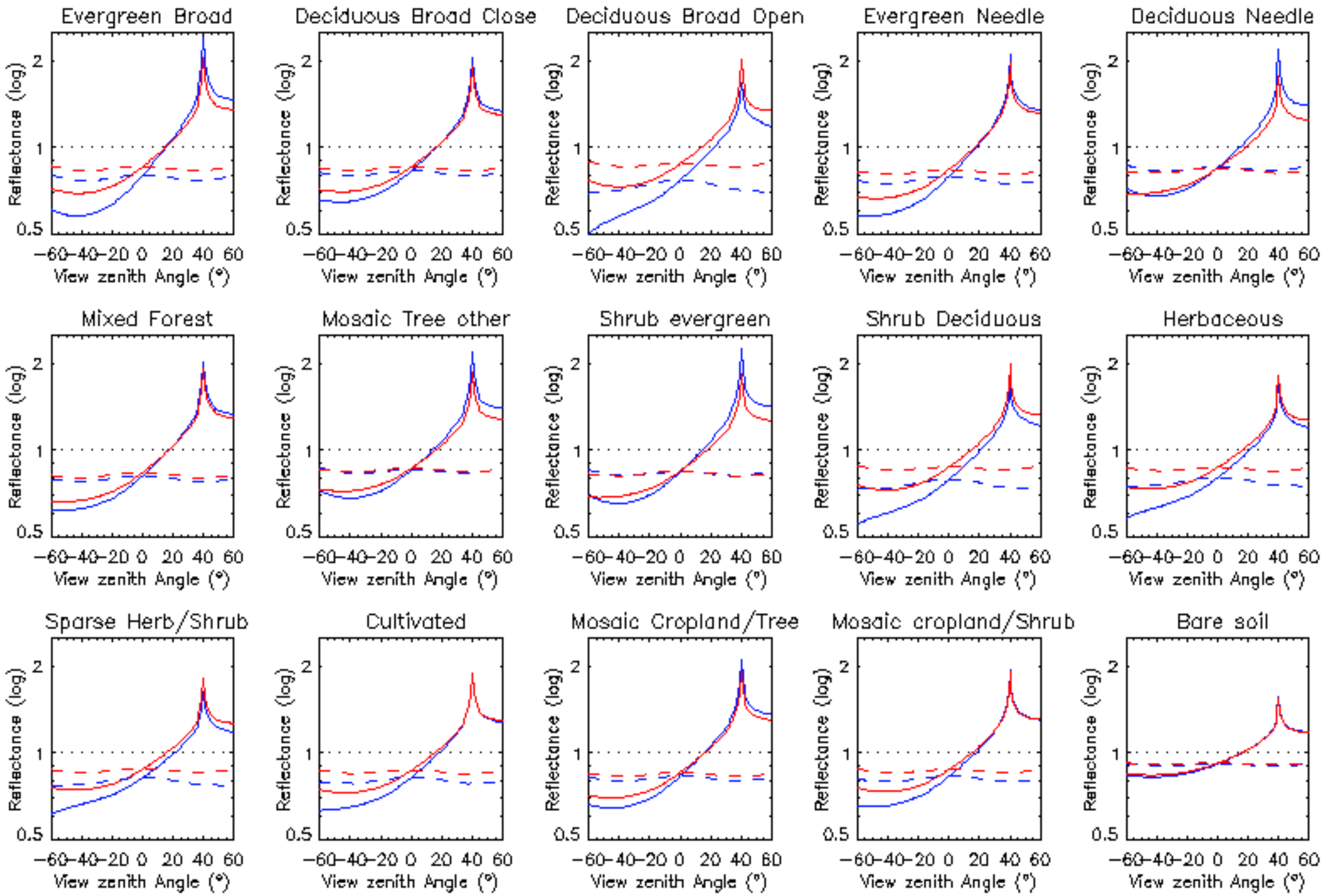
Bacour & Bréon., *Rem. Sens. Env.*, 2005

“Typical” BRDFs

865 nm
670 nm

——: Principal Plane

------: Perpend. Plane



These typical BRDFs can be used for a first order correction:

$$\rho^N = \rho(\theta_s,\theta_v,\varphi)\frac{BS(\theta_s^0,\theta_v^0,\varphi^0)}{BS(\theta_s,\theta_v,\varphi)}$$

Invert BRDF parameter per pixel

Search for BRDF parameters (V: k_1/k_0, R: k_2/k_0) that minimize the high frequency variations of the time series of $\rho(t)$, after directional correction

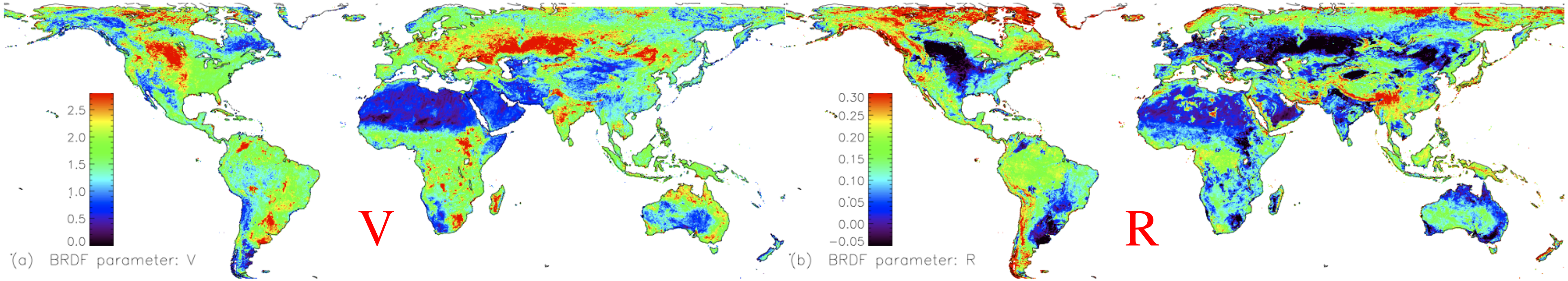
$$M = \sum_{i=1}^{N-1} \frac{\left(\rho_{i+1}\left[1 + VF_1^i + RF_2^i\right] - \rho_i\left[1 + VF_1^{i+1} + RF_2^{i+1}\right]\right)^2}{day^{i+1} - day^i + 1}$$

There is an analytical solution for the optimal (V, R)

$$\begin{pmatrix} \sum_{i=1}^{N-1} \Delta^i\rho F_1 \; \Delta^i\rho F_1 & \sum_{i=1}^{N-1} \Delta^i\rho F_1 \; \Delta^i\rho F_2 \\ \sum_{i=1}^{N-1} \Delta^i\rho F_1 \; \Delta^i\rho F_2 & \sum_{i=1}^{N-1} \Delta^i\rho F_2 \; \Delta^i\rho F_2 \end{pmatrix} \otimes \begin{pmatrix} V \\ R \end{pmatrix} = \begin{pmatrix} -\sum_{i=1}^{N-1} \Delta^i\rho \; \Delta^i\rho F_1 \\ -\sum_{i=1}^{N-1} \Delta^i\rho \; \Delta^i\rho F_2 \end{pmatrix}$$

Vermote et al., *IEEE TGARS*, 2008

Spatial structures of BRDF model

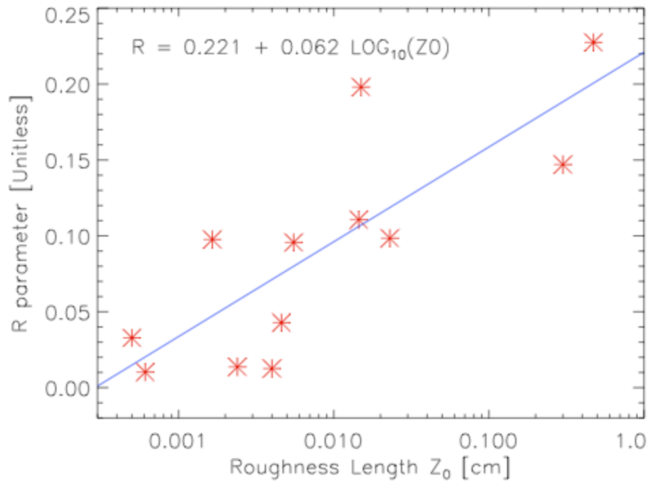


$$\rho(t,\theta_s,\theta_v,\varphi) = \rho_0(t)\left[1 + R\ F_1(\theta_s,\theta_v,\varphi) + V\ F_2(\theta_s,\theta_v,\varphi)\right]$$

There are some well-defined spatial structures that can be related to the surface cover.

Over desert areas, R can be linked to the surface roughness

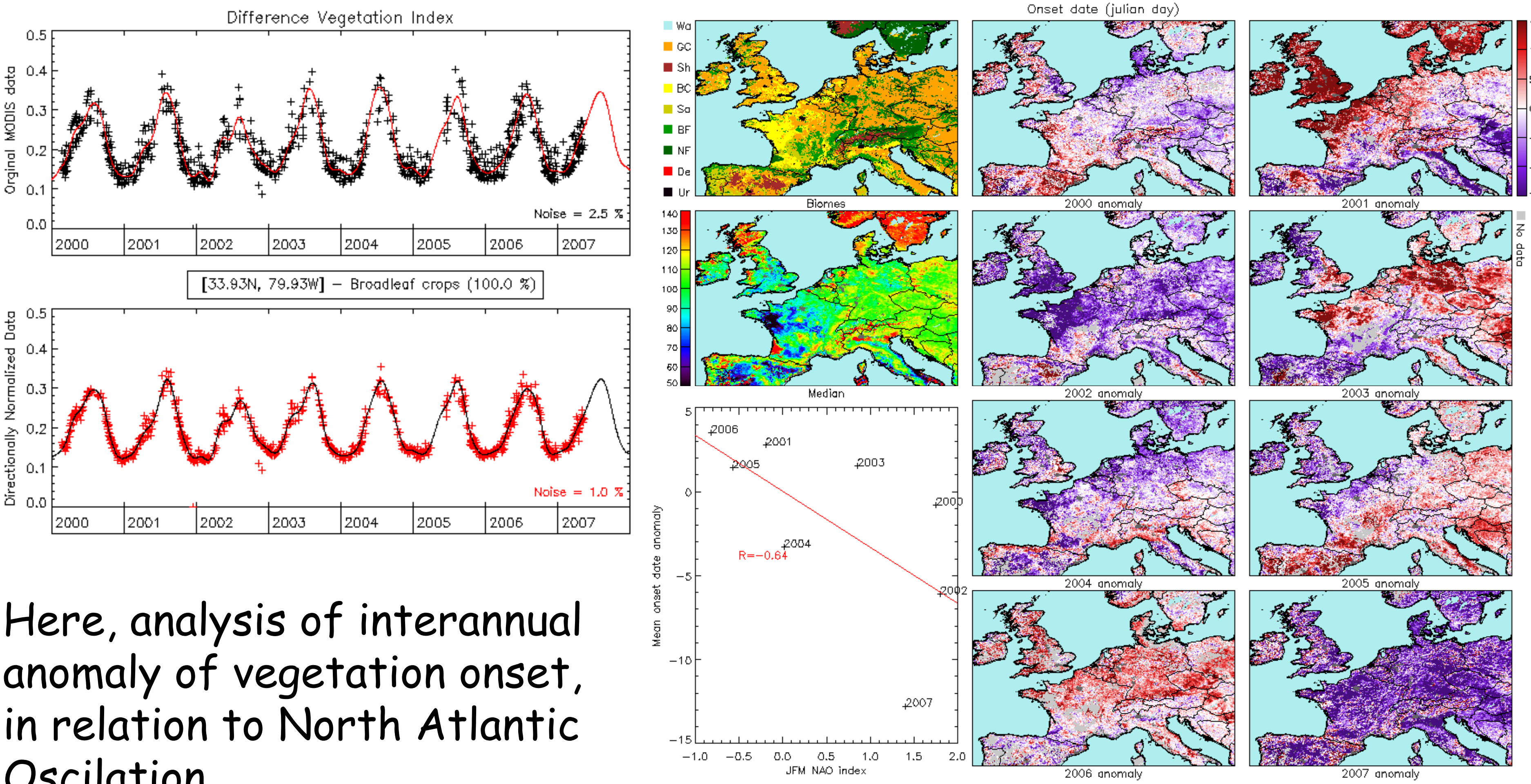
A proper interpretation is still needed…



Vermote et al., *IEEE TGARS*, 2008

Application: Vegetation Phenology

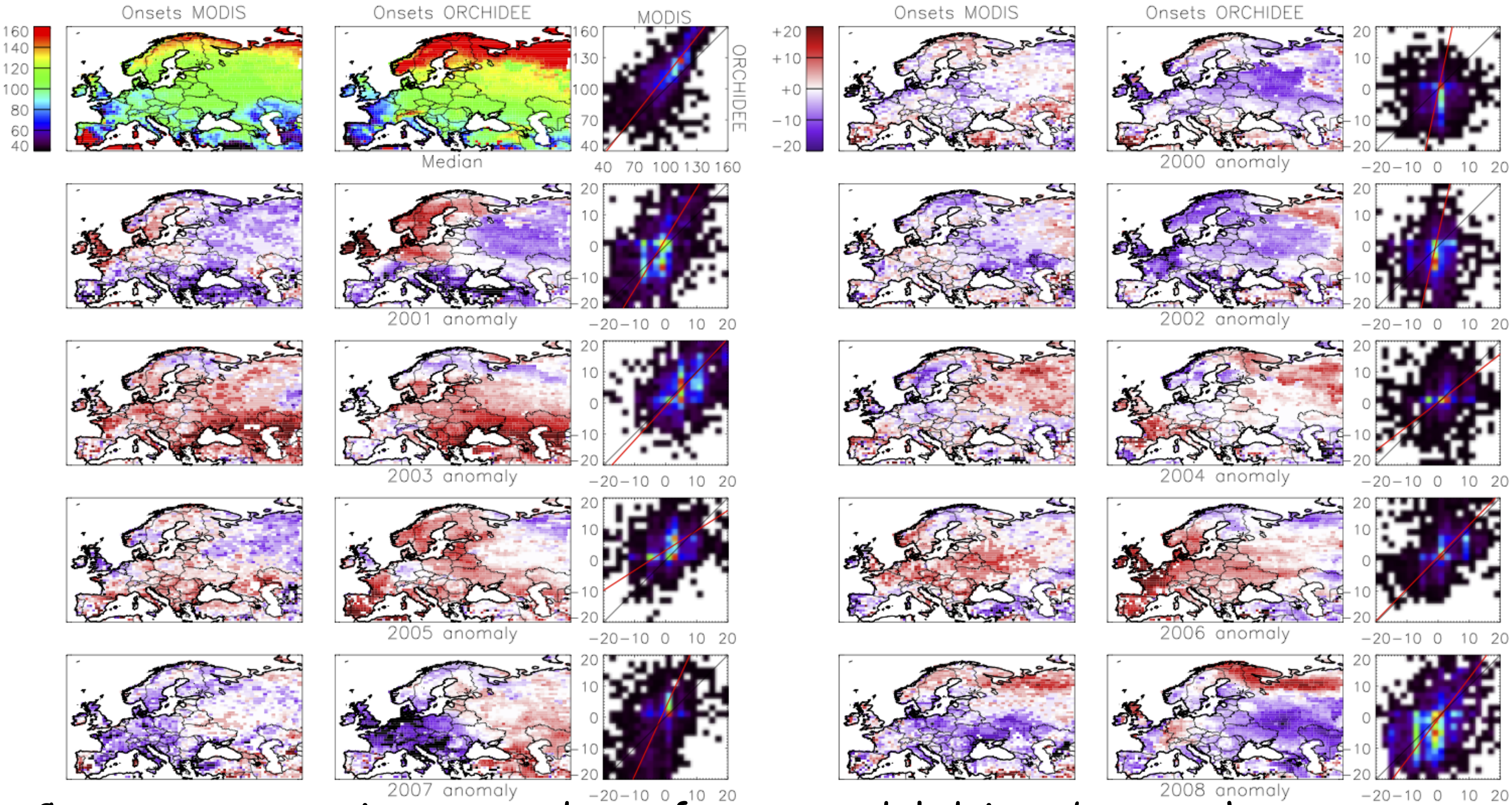
The corrected time series are cleaner than their original counterpart and can be used to extract "fine" signal



Here, analysis of interannual anomaly of vegetation onset, in relation to North Atlantic Oscilation

Maignan et al., *Rem. Sens. Env.*, 2007

Validate a vegetation model

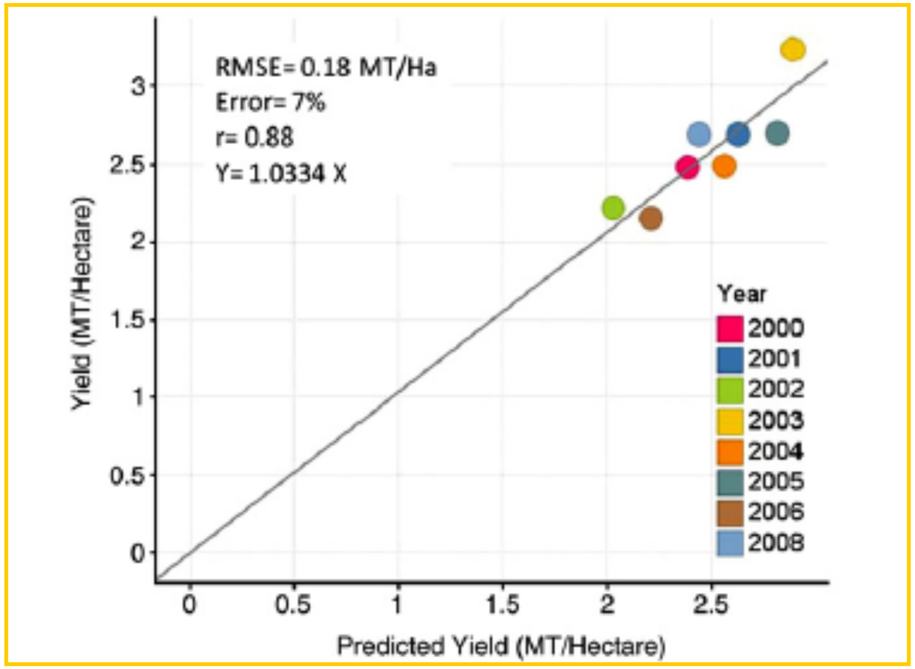


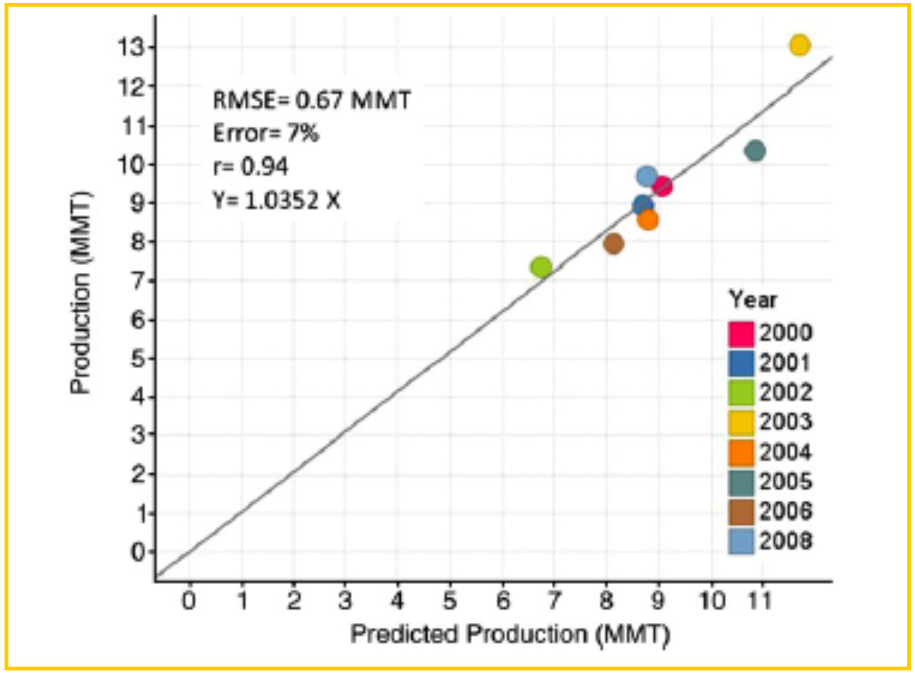
Compare vegetation onset dates from a model driven by weather to MODIS observations. Data assimilated to constrain model parameters.

Estimate crop yield

Corrected reflectance time series are used to identify max NDVI

Crop yield is estimated as a function of the max NDVI and surface fraction of winter wheat





The method was calbrated and validated over Kansas (see above)

It shows similar results over Ukraine, and makes it possible to estimate yield several weeks before harvest.

Becker-Reshef et al., *Rem. Sens. Env.*, 2007

Conclusions

Directional effects on the Earth reflectances are large (factor of 2 to 4 depending on wavelength)

Parasol is a great instrument to monitor reflectance directional signatures

There are simple analytical models (3 parameters) that reproduce accurately the observed signatures

These models can be used "per biome", or inverted over MODIS time series

Corrected time series are much smoother than their original counterpart, and can be used to extract fine signal

Applications include phenology monitoring and crop yield estimate